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***Abstract*—A major challenge for the European electronic industry is to enhance productivity while reducing costs and ensuring quality in development, integration and maintenance. Model-Driven Engineering (MDE) principles and techniques have already shown promising capabilities but still need to scale to support real-world scenarios implied by the full deployment and use of complex electronic components and systems. Moreover, maintaining efficient traceability, integration and communication between two fundamental system life-time phases (design time and runtime) is another challenge facing scalability of MDE. This paper presents an overview of the ECSEL[1] project entitled "MegaModelling at runtime – Scalable model-based framework for continuous development and runtime validation of complex systems" (MegaM@Rt2), whose aim is to address the above mentioned challenges facing MDE. Driven by both large and small industrial enterprises, with the support of research partners and technology providers, MegaM@Rt2 aims to deliver a framework of tools and methods for: 1) system engineering/design & continuous development, 2) related runtime analysis and 3) global model & traceability management, respectively. The diverse industrial use cases (covering domains such as aeronautics, railway, construction and telecommunications) will integrate and apply such a framework that shall demonstrate the validation of the MegaM@Rt2 solution.**

I. Introduction

In the global context, the European electronic industry faces stiff competition. Electronic systems are becoming more and more complex and software intensive [1], which calls for modern engineering practices to tackle advances in productivity and quality of these, now, cyber-physical systems [2].

Model-Driven Engineering [3] and related technologies promise significant productivity gains, which have been proven valid in several studies. However, these technologies need to be further developed to scale for real-life industrial projects and provide advantages at runtime. The ultimate objective of enhancing productivity while reducing costs and ensuring quality in development, integration and maintenance can be achieved by the use of techniques that integrate design and runtime aspects within system engineering methods incorporating existing engineering practices [4]. Industrial scale models, which are usually multi-disciplinary, multi-teams, combine several product lines and typically include strong system quality requirements, can be exploited at runtime by advanced tracing and monitoring. Thus, achieving a continuous system engineering cycle between design and runtime, ensuring the quality of the running system and getting valuable feedback from it that can be used to boost the productivity and provide lessons-learnt for future generations of products [5].

A major challenge in the Model-Driven Engineering of critical software systems is the integration of design and runtime aspects. The system behavior at runtime has to be matched with the design in order to fully understand the critical situation, failures in design and deviations from requirements. Many methods and tools exist for tracing the execution and performing measurements of runtime properties. However, these methods do not allow the integration with system models – the most suitable level for system engineers for analysis and decision-making.

The MegaM@Rt (MegaModelling at Runtime) proposal was submitted to the ECSEL in 2015. It received good evaluation scoring: 4.3 in Excellence, 4.6 in Impact and 4 in Implementation. The overly positive and instructive remarks motivated us to continue with MegaM@Rt2 in 2016 and a proposal was submitted for the research and innovation action in the call H2020-ECSEL-2016-RIA, by reinforcing the consortium and clearing the project details. The project officially started on April 01, 2017 and runs for 3 years.

The vision of MegaM@Rt2 is to create a scalable framework for model-based continuous development and validation of large and complex industrial systems by

[1]http://www.ecsel-ju.eu/web/index.php

exploiting important features of:

- MARTE, SysML and others to express both system functional and non-functional properties;
- model-based verification and validation methods at design time and runtime;
- methods for model management / megamodelling;
- methods for traceability over large multi-disciplinary models;
- methods for inference of system deviations from expected behavior and affected design elements;

II. Project Mission & Objectives

The MegaM@Rt2 mission is to create a framework incorporating methods and tools for continuous system engineering and validation leveraging the advantages in scalable model-based methods to provide benefits in significantly improved productivity, quality and predictability of large and complex industrial systems.

The above mission is realized through the following specific objectives:

- **Objective 1.** *MegaM@Rt2 continuous system engineering:* to develop scalable methods and tools for the integration of design artifacts resulting from heterogeneous engineering practices, including the modelling of functional and non-functional properties (e.g. performance, energy consumption, security and safety) based on requirements.
- **Objective 2.** *MegaM@Rt2 runtime analysis:* to develop integrated methods and tools for trace analysis based on probes injection to runtime artifacts, as well as improved monitoring in order to validate the system-level requirements.
- **Objective 3.** *MegaM@Rt2 (global) model management:* to develop scalable infrastructure for efficient handling and management of numerous, heterogeneous and large models potentially covering several functional and non-functional domains.
- **Objective 4.** *MegaM@Rt2 unified traceability management:* to develop holistic traceability methods and tools 1) capable to link and manage models and their elements from different tools as well as 2) suitable for large distributed cross-functional working teams and 3) allowing to integrate the feedback to the system level models.
- **Objective 5.** *MegaM@Rt2 demonstrators validation:* to develop specific demonstrators and validate MegaM@Rt2 technologies through 10 complementary industrial case studies.
- **Objective 6.** *MegaM@Rt2 market uptake:* to prepare exploitation of the MegaM@Rt2 technology through open source and commercial tools.

III. Concept and Approach

In the past, Model-Based Engineering principles and techniques have already shown promising capabilities that have been experimented in a context having software components relying on hardware configurations and their interactions e.g. with their underlying environment, being very often numerous, complex, heterogeneous and strongly interrelated. However, they have generally failed in terms of 1) scalability to support real-world scenarios implied by the full deployment and use of complex electronic components and systems (ECS) and 2) maintaining efficient traceability, integration and communication between two fundamental system life-time phases which are design time and runtime, notably as far as non-functional properties and their verification & validation aspects are concerned.

As a consequence, the overall idea of MegaM@Rt2 is to scale up the use of model-based techniques by offering proper methods and related tooling, interacting with both design time and runtime, as well as to validate the designed and developed approach in concrete industrial cases involving complex ECS. To this intent, MegaM@Rt2 proposes an overall model-based approach combining existing techniques to be enhanced when relevant, and novel ones to be developed when needed. A fundamental challenge notably resides in providing efficient traceability support between the two levels i.e. from design models to runtime ones and back. Moreover, modern large-scale industrial software engineering processes require thorough configuration and model governance to provide the promised productivity gains. Thus, a scalable megamodelling approach is required to manage all the involved artifacts e.g. the many different models, corresponding work flows, configurations, etc. and to better tackle their large diversity in terms of nature, number, size, complexity, etc.

To cover all these topics and deal with the complete value chain, MegaM@Rt2 brings together prominent tool vendors and research organisations with state-of-the-art methods and tools to be validated in highly relevant European industrial case studies. The end users from the space, naval, railway, smart grid, smart warehouse and telecom industry domains aim to drive the project by providing real-world requirements and case studies as well as by validating and endorsing the MegaM@Rt2 results.

Figure 1 provides an overview of the MegaM@Rt2 global approach and emphasizes its key principles and concepts, relating them to the corresponding work packages (Section IV). A set of current engineering practices based on SysML, AADL, EAST ADL, but also Matlab/Simulink, AUTOSAR and Method B or Modelica, each one producing as set of specific design models, requirement specifications and resulting software artefacts are integrated into a global system model providing a complete view of the cyber-physical system, and detailing the component, behaviour and desired quality properties of the system. These properties are then object of exhaustive continuous testing and monitoring in the runtime environment (thanks to the configuration of the target platform and the injection of probes in the software) to detect deviations in real-time. These deviations plus all the traces information collected in the process are analyzed to detect the impacted components in the integrated view of system models. When possible, automatic repairing suggestions will be provided to correct the issue and reconfigure or redeploy the system to start the next iteration of the continuous integration process.

IV. Work Packages

The main expected result of MegaM@Rt2 is a practical framework incorporating methods and tools for continuous system engineering and validation. As introduced earlier, its overall goal is to leverage the advantages of scalable model-based methods to provide significantly improved productivity, quality and predictability of large and complex industrial systems. This framework will be composed of three main tool sets for 1) system engineering/design & continuous development, 2) related runtime analysis and 3) global model & traceability management (respectively). As a consequence, we have organized the project around the research work and realization of these tool sets. Their integration and actual application onto a set of concrete use cases, covering different industrial domains, is also a central aspect of the project.

To reflect these principles, the project has been organized in 7 complementary work packages (WPs):

- WP1. Case Study Requirements Analysis & Architecture Specification;
- WP2. MegaM@Rt2 System Engineering;
- WP3. MegaM@Rt2 Runtime Analysis;
- WP4. MegaM@Rt2 Global Model & Traceability Management;
- WP5. Integration, Case Study Development & Evaluation;
- WP6. Dissemination and Exploitation;
- WP7. Management.

The work to be realized in the project is strongly requirements-driven. These requirements are extracted from the use cases as part of WP1, in collaboration between the use case providers (mainly large industrial companies) and the technical providers (composed of both service/product companies and experienced researchers from academia). This same WP is also in charge of defining the overall architecture (conceptual and technical) of the MegaM@Rt2 solution. Most of the research and development effort is concentrated in WP2, WP3 and WP4, which aim at providing the three tool sets previously mentioned. Within WP5, these technical results will be then integrated together, applied on the use cases and finally evaluated for further improvement. The work in the project will follow an iterative and incremental approach divided into three consecutive phases. In the first phase, we will specify the requirements, validation scenarios, global architecture and roadmap. In addition, case study partners will experiment with baseline technologies while technology providers will develop the first set of prototypes. In the second phase, we will consolidate these prototypes, integrate them in a first release of the MegaM@Rt2 framework and run an initial set of validation scenarios. Based on the obtained results, in the third phase, we will integrate and validate the technical solutions, provide final validation and experience reports from the use cases (as well as a final management report). In parallel, the dissemination (academic or industrial, including the relation with the standardization organizations such as the Object Management Group - OMG) and exploitation (e.g., consortium and individual business plans) activities will be conducted in WP6. The general project management and reporting activities will be performed under the umbrella of WP7. We will now present a brief description of each WP.

WP1 - Case Study Requirements Analysis and Architecture Specification. This WP gathers the work on the case studies definition and requirements analysis (by end-users) with the global architecture and road map specification (by technology providers). The industrial partners will set real requirements for research and technology providers. They will closely collaborate and be integrated in the development teams, providing regular feedback on the elaborated technologies. This WP also concentrates on the validation scenarios, i.e. end-to-end demonstrators for the MegaM@Rt2 solutions in varied industrial contexts. End-users will develop methods for gathering the data needed for qualitative and quantitative verification of MegaM@Rt achievements. They will run the related experiments in a cost-efficient manner, and will provide representative evaluation of the technologies for large scale usage. From their side, the technology partners will define the architecture and a detailed road map for the technical developments.

WP2 - MegaM@Rt2 System Engineering. This WP gathers the activities related to the definition of the required domain-specific languages (DSLs) to support model-based system design, and of the methods and tools to develop integrated system models. One of the strongest points of model-based approaches lies in the support for separation of concerns and definition of specific architectural views. Specific views focus on specific areas of the development from system to software level, including the system functional, logical and physical decomposition, identification of software and hardware components, definition of functional and non-functional properties, software architecture, data, behavior and algorithmic modeling. This WP concentrates on all the modelling and tooling aspects of MegaM@Rt2. The goal is first to provide the foundations for WP3 and WP4, and later to design, develop and support the MegaM@Rt2 system engineering tool set to be used by industrial partners in WP5.

WP3 - MegaM@Rt2 Runtime Analysis. This WP focuses on the usage and definition of models at runtime level, and on the associated techniques or methods. Models at runtime can be designed or obtained from the system itself. For instance, logging or monitoring the system under the form of models can be performed jointly with the system execution and can help in ensuring a correct system execution. Afterwards, such models can also be analyzed to enhance design models from WP2 and are thus entries of the tools and methods of WP4. Verification and validation issues can be managed directly at runtime, enabling to detect problems that can be solved at runtime or brought back to design level. This can be achieved by checking the expected behavior according to functional and

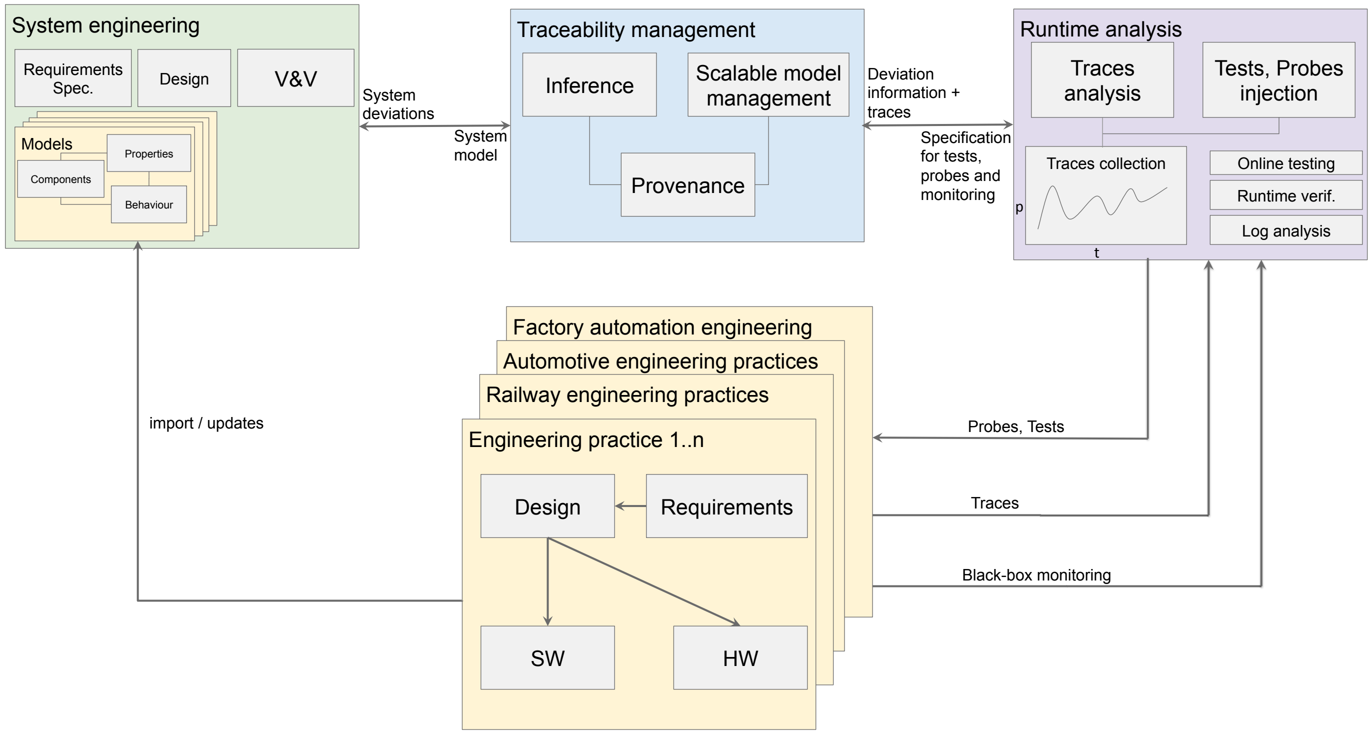

Fig. 1. The MegaM@Rt2 Overall Approach.

non-functional properties embedded in the design models, or by analyzing jointly runtime models with the actual system execution to determine if the system fulfills its specifications. To this intent, this WP will notably provide on-line testing and verification techniques.

WP4 - MegaM@Rt2 Global Model and Traceability Management. This WP focuses on megamodeling, or global model management, in which models for design time (WP2) and models for runtime time (WP3) are managed and aligned all together. A particular focus is put on various scalability topics: not only the size of the models is larger, but there is larger number of model users with different roles; there are various kinds of languages (DSLs) involved for different needs, including e.g. user interface (UI) related languages, and various transformations related to them. The second (and directly related) focus of this WP is on traceability between design time and runtime, as not in all cases the same model can be used for both purposes. WP4 also provides implementation of the tooling for scalable megamodeling/traceability and guidelines for their deployment and practical use in case studies. The WP delivers its results incrementally, notably by collecting progressively feedback on the developed features from their application to the project use cases.

WP5 - Integration, Case Study Development and Evaluation. This WP provides specific industrial demonstrators as case studies from various and varied application domains such as aeronautics, railway, construction and telecommunication. The main goal of WP5 will be to integrate the different technical developments realized in WP2, WP3 and WP4. It will also be in charge of conducting controlled experiments on the case study partners premises, as defined in WP1. Partners in WP5 will perform a preliminary evaluation as feedback for WP2-3-4, and a strong interaction between use cases providers and technology providers is expected. Finally, WP5 will perform the final integration and consolidation of the MegaM@Rt2 solution, as well as the overall validation the obtained results.

WP6 - Dissemination and Exploitation. This WP concentrates on the project impact and community building activities. These activities will provide a solid base to identify the key stakeholders for sustainable exploitation, dissemination, communication and standardization. They will indicate the who, how and why of project interactions and, when coupled with further analysis and tools in each task, determine the specific course of action and measurement for maximum impact and effective use of resources. To this intent, different techniques will be used including the value chains and networks, influence/importance matrices, PEST, SWOT, Porters Five Forces, Blind Spot Analysis or Wardley Mapping. Although the various stakeholders have their own specific ends, a common work will provide a shared footing and a coherent strategy at project level.

WP7 - Management. This WP gathers all the activities related to the management of the MegaM@Rt2 project and its consortium of partners. This mostly includes the mandatory official monitoring and reporting tasks (to the ECSEL Joint Unit and the European Commission). The overall objective is to ensure a smooth running of the project and efficient collaborations between all the involved partners. As fundamental to the success of the project, this WP will notably coordinate the establishment of a proper quality plan to be applied to all MegaM@Rt2 results. It will also deal with the important risk management and Intellectual Property (IP) issues that may appear during the course of the project.

V. Industrial Impact

The ECSEL[2] program seeks to invest in projects that strengthen the industrial competitiveness, enable economic growth and improve sustainability. Europe has a reasonably strong position in the world embedded market (30%), but this is falling as other geographies grow - some at the vanguard and others catching up. The MegaM@Rt2 consortium argues that investment in capability of the software development tools market, although only a fraction, has a very large pay-off. We have seen that the software component of the systems is increasingly more growing in importance. As the hardware becomes commoditized, the added value will rapidly shift to the software. Achieving technological, and consequently competitive superiority, in software development tools will allow European firms to participate with greater dominance in the overall software market.

Specifically, MegaM@Rt2 achieves this in part through reducing development and exploitation costs and in part by allowing mastery of more complex systems. Reducing development costs and time-to-market is a competitive advantage, allowing on, one hand, greater innovation in each product and allowing faster reaction to hardware changes or new usage scenarios on the other. As the Cyber-Physical Systems' world evolves, the agility to react rapidly to new opportunities is a critical success factor for businesses. Mastering ever more complex systems allows new usage scenarios to emerge, based on optimization of greater problems or more optimized solutions for existing ones.

Improved software will allow the bigger players to better position their overall solutions and engender small businesses fulfilling niche needs for high end bespoke software. Investment in this area is timely and appropriate. The small scale and the under-developed capacity of this market segment can lead to large pay-offs in the related fields, whereas the overall embedded systems is of such a magnitude that it requires vast research investment for significant progress.

The MegaM@Rt2 objectives address several market trends in Cyber-Physical Systems:

- Increasing inclusion of advanced techniques like model-based design, development and validation.
  - MegaM@Rt2 supports this trend in the technologies provided through industrial case studies.
- Technology availability and support during extended period (e.g. up to 30 years in the railways).
  - MegaM@Rt2 open source solutions support this requirement.

[2]http://www.ecsel-ju.eu/web/index.php

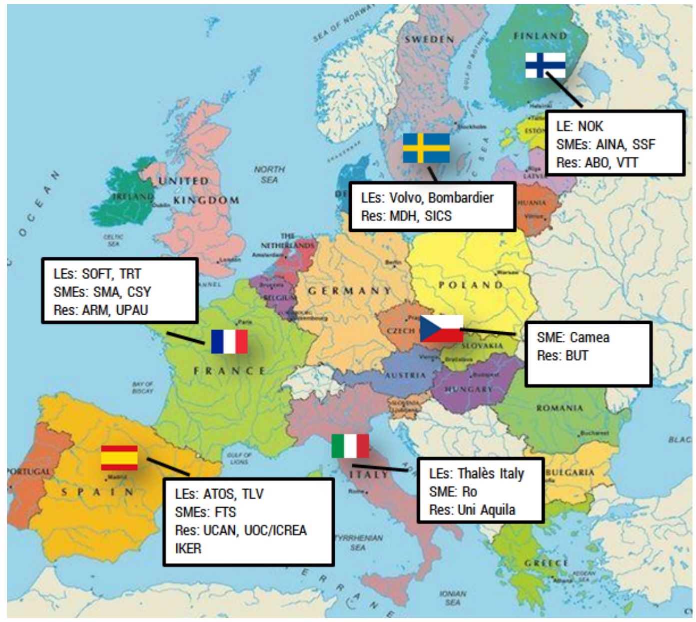

Fig. 2. The MegaM@Rt2 Consortium.

- Convergent combination of multi-domains industrial practices.
  - MegaM@Rt2 supports this challenge with multi-domain case studies.
- More and more complex (structure/behaviour), connected systems.
  - With a clear support for megamodelling and system analysis at runtime, MegaM@Rt2 supports this trend.

VI. Consortium

The MegaM@Rt2 consortium is large and is composed of partners having different complementary profiles. It brings together 27 partners coming from 6 European countries, each of which constitutes a national consortium (France, Spain, Italy, Sweden, Finland and Czech Republic). See Figure 2 (the abbreviations used in partner names are described in Sections VI-A, VI-B, VI-C).

The project consortium is strongly industry-led and consists of 7 Large Enterprises (LEs) and 9 Small and Medium Enterprises (SMEs) accompanied by 11 universities or research and technology transfer organizations. An adequate level of balance has been achieved by choosing SOFTEAM as a technical coordinator (a French LE with comprehensive experience in managing large research projects) while the managerial coordination is led by Mälardalen University (Sweden), which also has an extensive experience in both, participating and managing, EU projects. A suitable management strategy has been evolved by bringing together partners that know each other and have already collaborated in the past [6]. To setup the consortium, a complete value-chain has been taken into account by selecting case study owners, technology providers and research partners (Figure 3):

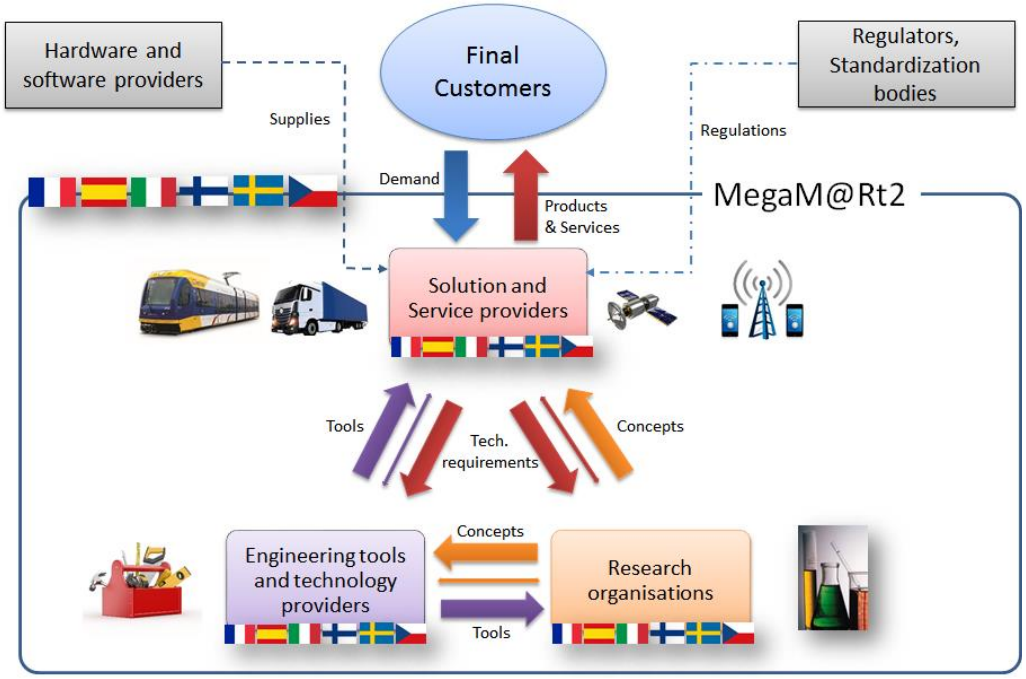

Fig. 3. The MegaM@Rt2 project involves partners covering the market and technology value chains.

- **Case study owners and end-user partners.** Providing knowledge of both end-users needs and development scenarios for complex industrial systems.
- **Technology and service providers partners.** Providing knowledge and tools in MDE, HW and SW synthesis, collaborative modelling and standardization.
- **Research partners.** Providing knowledge in megamodelling, MDE, code generation, Verification & Validation and logs analysis.

In the remaining of the section, all the members of the consortium are briefly described with respect to their role in the project.

A. *Case study owners and end-user partners*

Eight industrial partners will play the role of case study providers and end-users as described below.

Thalès RT - TRT (FR) provides a case study in avionics domain and will lead the validation scenarios definition. TRT has an extensive experience with MDE.

Telvent Energia - TLV (ES) provides a case study in smart grid domain and will lead the case studies validation activities.

Ikerland - IKER (ES) provides a case study in smart warehouse domain and will lead the experiments with baseline technologies.

Tekne - TIT (IT) provides a case study in short-range communications domain and will lead the requirements analysis activities.

Nokia - NOK (FI) provides a case study in the telecommunications domain and will lead the case studies development activities.

Camea - CAM (CZ) provides the case study in vision-based intelligence.

Bombardier Transportation Sweden AB - BT (SE) provides a case study of their train control and management system (train/railway domain).

Volvo Construction Equipment - VCE (SE) provides a case study in the vehicular domain (VCE's electrical and electronic system technology platform).

B. *Technology and service providers partners*

Seven industrial partners will play the role of technology and service providers as described below.

Softeam - SOFT (FR) will contribute with its expertise in MDE as a tool vendor for Modelio work bench and as an active member of the Object Management Group. SOFT's technical contribution will include the work on user interface generation from Interaction Flow Modeling Language (IFML) specification, code generation with "MDD+aspects" approach and scalable model management with model fragments infrastructure.

Smartesting Solutions & Services - SMA (FR) will lead the work package on runtime methods and tools. SMA's main contribution will be in online testing techniques development. SMA will contribute to baseline technologies with SmartTesting CertifyIt technology.

ATOS (ES) will lead the MegaM@Rt2 framework integration and the exploitation work package. ATOS will contribute to model simulation task force and code generation by providing development for Foundational UML (fUML) and AspectJ.

Fent Innovative Software Solutions - FTS (ES) expertise is focused on the development of execution platforms for mixed criticality systems. It is specialized in: (1) Design and development of hypervisor technology; (2) Design and development of real-time operating systems; (3) Adaptation of operating systems to be executed as a partition on top of XtratuM hypervisor. FTS will mainly be involved in Runtime work package and will provide its expertise in execution platforms.

Intects - INT (IT) contributes to the MegaM@Rt2 framework with the CHESS model-driven, component-based methodology and tool chain for the development of high-integrity systems for different domains. INT participates in the development of the CHESS open source project delivered under Eclipse/Polasys. CHESS relies on MARTE, with focus on non functional properties modelling, analysis and correct-by-construction code generation.

Ro Technology - RO (IT) will provide advanced design, development and V&V Techniques.

Space Systems Finland - SSF (FI) will contribute to the MegaM@Rt2 framework with the LIME toolset for runtime monitoring of the implementations and automatic test generation, which was partially funded by SSF. SSF will work on integrating the toolset to other MegaM@Rt2 tools. SSF will also participate in the application of the tools to the case studies provided by other Finnish partners. Additionally, SSF will share its extensive knowledge of verification and validation methods for safety-critical systems.

C. Research partners

Ten partners will drive the research activities of the consortium and are presented below.

ARMINER - ARM (FR) will lead activities on scalable model management & traceability. ARM has an extensive expertise in MDE, being the creators of several Eclipse-based modeling solutions such as ATL, AM3, Neo4EMF or EMF Views.

The **Universite de Pau et de pays de l'Adour - UPAU (FR)** will lead activities on models' execution techniques development and will contribute with the PauWare library.

The **Universidad de Cantabria - UCAN (ES)** will lead development of the design level verification and validation methods tools. In particular, UCAN contributes with eSSYN tool suite featuring software synthesis technology.

The **Universitat Oberta de Catalunya - UOC (ES)** will lead development of scalable model-based techniques. For the baseline technology, UOC contributes EMFtoCSP verification tool suite.

The **University of L'Aquila - UAQ (IT)** will lead the traceability and provenance task force.

The **Abo Akademi University - ABO (FI)** will lead the runtime verification task and will further contribute to all the work packages providing expertise in Aspects Oriented Modelling. ABO contributes to the baseline technologies with UPAAL TRON tool suite.

VTT - FI will lead development activities in logs analysis with machine learning and data mining technologies.

SICS Swedish ICT Västeras - SICS (SE) will contribute in runtime verification and validation methods and their implications and required support from higher modelling levels, in particular with its methods for test process optimization at integration testing level.

Mälardalen University - MDH (SE) will contribute in verification and validation at design-time, verification and testing at run-time, integration of megamodelling and traceability within the overall tool chain.

Brno University of Technology - BUT (CZ) will primarily contribute in runtime model optimization and validation through classification and scheduling methods from historical performance data. They will also support CAM in the vision-based intelligence use case.

VII. Conclusion

This paper presented the MegaM@Rt2 ECSEL project. It notably provided the global context and motivation for this project, introduced its mission and targeted objectives, described its general organization in terms of work packages and detailed the composition of its large supporting consortium. As explained in this paper, MegaM@Rt2 mainly intends to create a scalable model-based framework for dealing with the continuous development and validation of the software parts of large and complex industrial CPSs. This framework will notably focus on relating together the actual executions of these systems (i.e., runtime) with the way they are currently specified, developed and maintained (i.e., design time). While there is already quite a lot of support for these two dimensions separately, there is currently no real support for an efficient integration and feedback loop between design time and runtime. We plan to practically realize this by providing the required management and traceability support between all the involved models (both at design time and runtime). The obtained results will be experimented on 8 different use cases covering different industrial domains such as aerospace, railway, telecommunication, networks and construction equipments. In addition to scientific progress in the CPSs and modeling/MDE domains, industrial partners are expected to gain concrete benefits in terms of improvements to their system reliability and decrease in development and maintenance costs.

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References

[1] P. Wallin, S. Johnsson, and J. Axelsson, "Issues Related to Development of E/E Product Line Architectures in Heavy Vehicles," in *42nd Hawaii International Conference on System Sciences (HICSS)*, 2009.

[2] S. K. Khaitan and J. D. McCalley, "Design Techniques and Applications of Cyberphysical Systems: A Survey," *IEEE Systems Journal*, vol. 9, no. 2, pp. 350–365, 2015.

[3] D. C. Schmidt, "Guest Editor's Introduction: Model-Driven Engineering," *Computer*, vol. 39, no. 2, pp. 25–31, 2006.

[4] L. Baresi and C. Ghezzi, "The Disappearing Boundary Between Development-time and Run-time," in *Proceedings of the FSE/SDP Workshop on Future of Software Engineering Research (FoSER)*. ACM, 2010.

[5] B. Fitzgerald and K.-J. Stol, "Continuous Software Engineering: A Roadmap and Agenda," *Journal of Systems and Software*, vol. 123, pp. 176 – 189, 2017.

[6] S. E. Cross and T. Felis, "A Systems Engineering Approach to Systematic Innovation in an Industry-University Collaboration," in *2016 IEEE European Technology and Engineering Management Summit (E-TEMS)*, 2016.